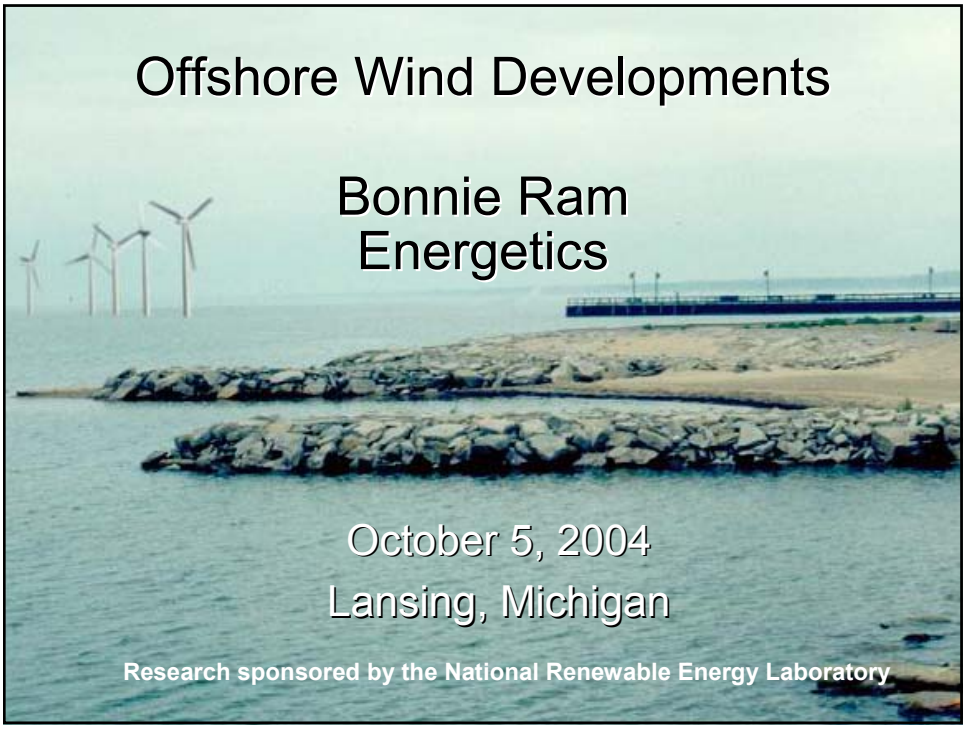
Offshore Wind Developments

Bonnie Ram
Energetics



October 5, 2004
Lansing, Michigan

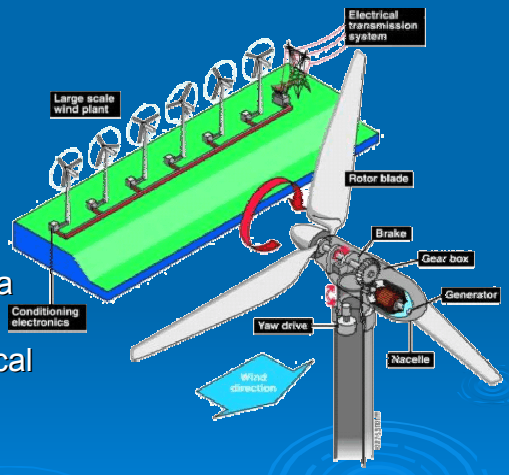
Research sponsored by the National Renewable Energy Laboratory

This Presentation

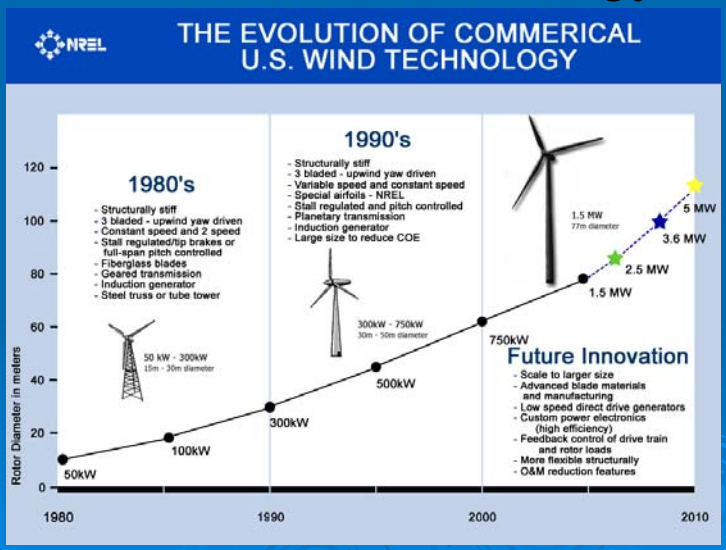
- Wind Overview
- Why Move Offshore?
- Current Activities
- Factors Affecting Costs
- Technology Snapshot
- Why Go into Deeper Water?
- NREL Research
- Applicable Regulations
- Current Events
- Lessons Learned
- Summary
- References

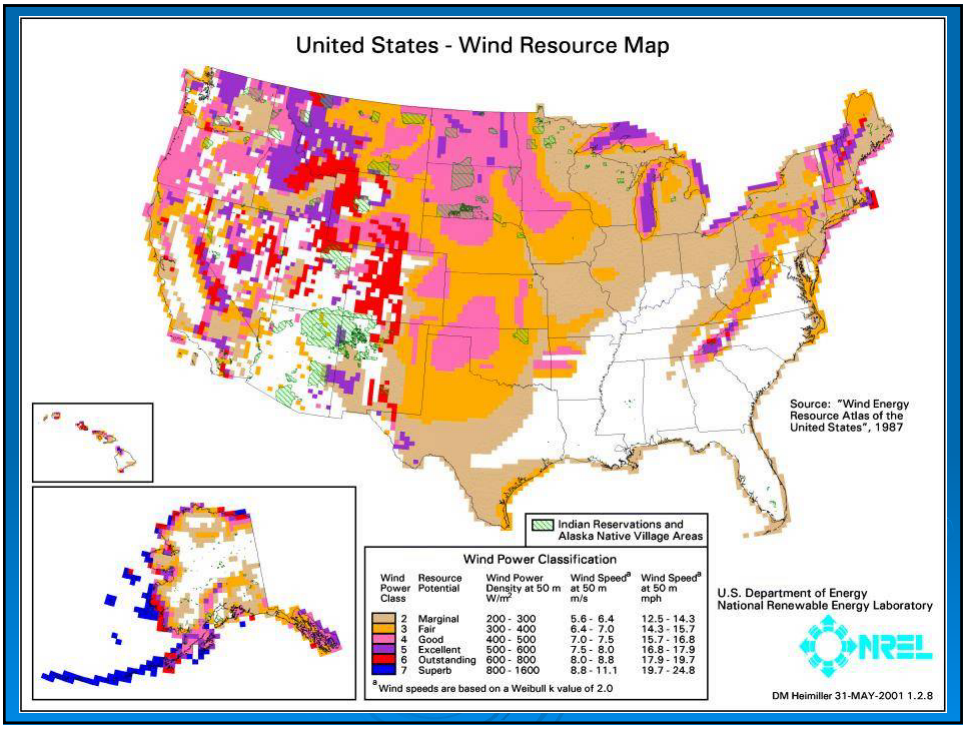
Wind Energy Technology

At it's simplest, the wind turns the turbine's blades, which spin a shaft connected to a generator that makes electricity. Large turbines can be grouped together to form a wind power plant, which feeds power to the electrical transmission system.



Evolution of Commercial U.S. Wind Technology





Cost of Energy on Land

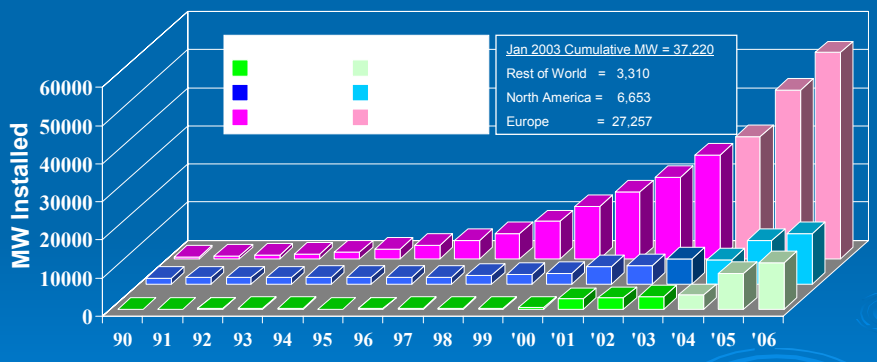
NSP 107 MW Lake Benton wind farm
4 cents/kWh (unsubsidized)

1979: 40 cents/kWh

2003: 3.5 to 5.5 cents/kWh at 15 mph sites (30 ft height)

- Increased Turbine Size
- R&D Advances
- Manufacturing Improvements

Growth of Wind Energy Capacity Worldwide



Sources: BTM Consult Aps, March 2003
Windpower Monthly, January 2004
*NREL Estimate for 2004

Worlwide Market

- Total installed: 41,000 MW
  - 613 MW -- offshore
- Average growth during last 6 years: 32%
- 80% installed power in only 5 countries (G,DK,S,USA,India)
- Installed power will increase considerably
- Turn-over in 2003 world-wide appr. $3 billion
- Total value of presently installed power appr. $9 billion

Source: Jos Beurskens Energy Resource Centre of the Netherlands (ECN)

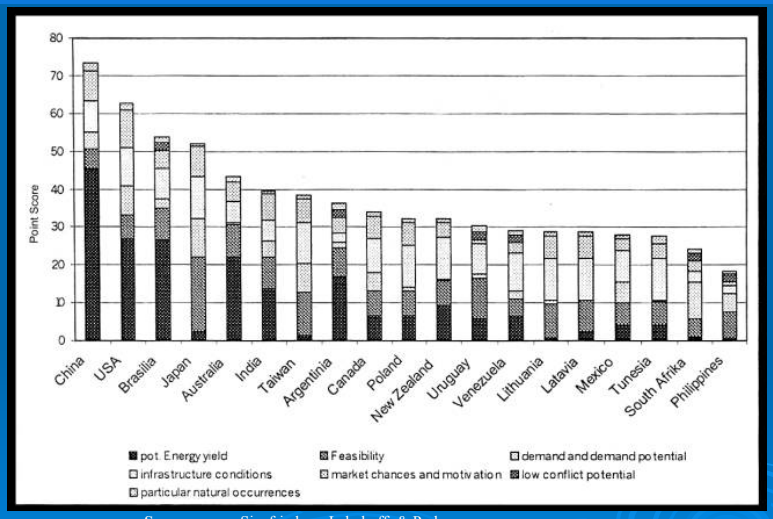
National Impact on Energy Balance

Country	% of National Elec. Supply	Installed Power (GW)
Denmark	20	3.2
Germany	6	16
Spain	5	6.5
Netherlands	2	1
India	0.8	3.2
USA	0.35	6.5
EU (15)	2.5	30
World	0.5	41

> 75,000 jobs

Source: Jos Beurskens, ECN

Offshore Wind Energy Potential Outside the European Union

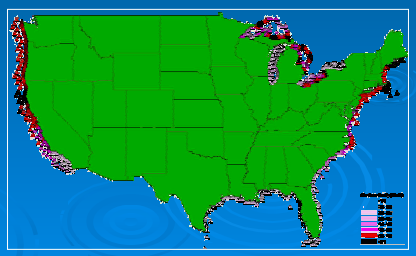


Source: Siegfriedsen, Lehnhoff, & Prehn
aerodyn Engineering, GmbH

Conference: Offshore Wind Energy in the Mediterranean and other European Seas
April 10-12, 2003 - Naples, Italy

Why Move Offshore?

- Higher-quality wind resources
  - Reduced turbulence
  - Increased wind speed
- Economies of scale
  - Avoid logistical constraints on turbine size
- Proximity to loads
  - Many demand centers are near the coast
- Increased transmission options
  - Access to less heavily loaded lines
- Potential for reducing land use and aesthetic concerns



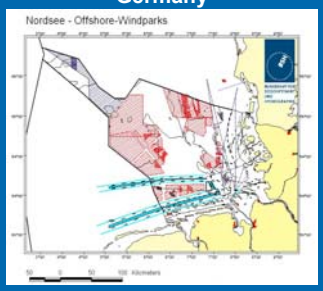
Presently Installed Offshore

- North Sea conditions: 249.0 MW (41%) 160 MW under repairs
- Shallow, sheltered waters: 364.7 MW (59%)
- Total (all in Europe): 613.7 MW (100%)

Source: Jos Beurskens, ECN

Europeans are Planning on a National Scale

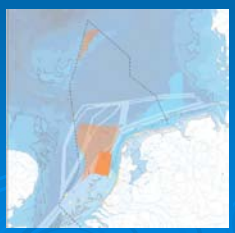
Germany



Denmark

Great Britain

Belgium



Netherlands

Source: Jos Beurskens, ECN

Status of U.S. Offshore Wind Projects

Applicant	Project Location	Application Filed	Status
Cape Wind	Nantucket Sound	November 2001	Draft EIS expected this year
Bald Eagle Power	Long Island Sound	May 2002	The applicant is revising the application
Greenlight	Lake Erie	May 2003	Project on hold
Winergy	Plum Island, NY	June 2003	Incomplete Application
Winergy	Smith Island, VA	July 2003	Application administratively withdrawn
Winergy	Asbury Park, NJ	NA	No meeting scheduled
Winergy	4 sites in New Jersey	NA	Pre-application meeting Nov 2002
Winergy	Indian River, Delaware	NA	Pre-application meeting Feb 2003
Florida Power and Light	Long Island Sound	TBD	Utility awarded the competitive project

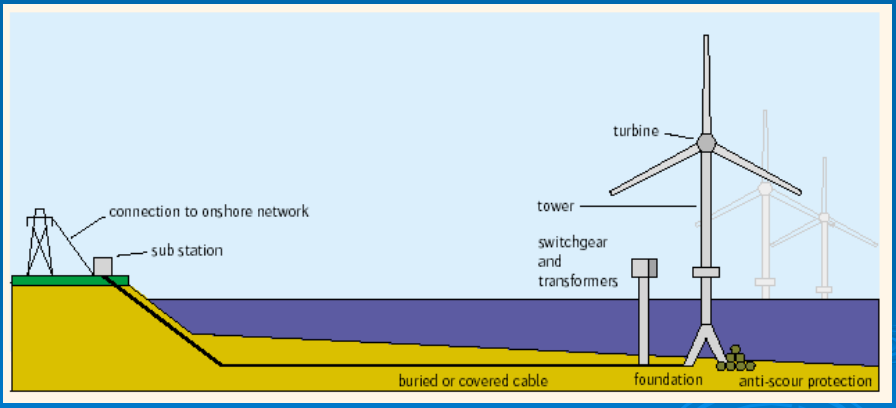
Factors Affecting Cost of Energy

- Total installed costs
  - Turbines (number & size)
  - Foundation
  - Electrical System (cable distance)
  - Installation
- Energy produced
  - Wind resource
  - Turbine operating characteristics
  - Turbine spacing
- Operation and Maintenance
- Financial considerations (e.g., interest rates)
- Location and water depth

Social (External) Costs of Electricity Production

- Costs not accounted for directly in fuel price or production costs
- Health and Ecological Effects
  - Air pollution & respiratory illness
  - Damage due to climate change
- Typical estimates:
  - Coal: 2-15 cents/kWh
  - Gas: 1-4 cents/kWh

Offshore Wind Farm Layout



GE Wind Energy
3.6 MW Prototype

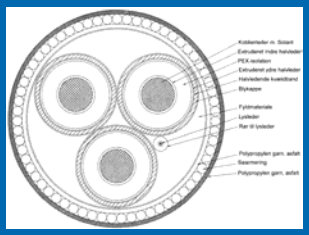
- Design concept similar to offshore GE 1.5 / 70.5
- Offshore GE 3.6 MW 104 meter rotor diameter
- Offshore design requirements considered from the outset:
  - Crane system for all components
  - Simplified installation
  - Helicopter platform

Enercon
Offshore Prototype

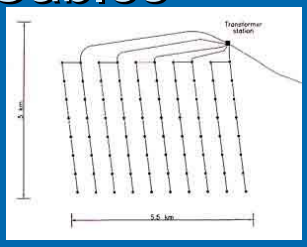
Enercon 4.5MW 112 meter rotor

440 metric tonnes

Electrical Cables



Cable cross section



Typical cable layout

Cable laying ship

Cable trencher

Illustrations from www.hornsrev.dk

Offshore Installation (1)

Pile driving foundation

Installing tower

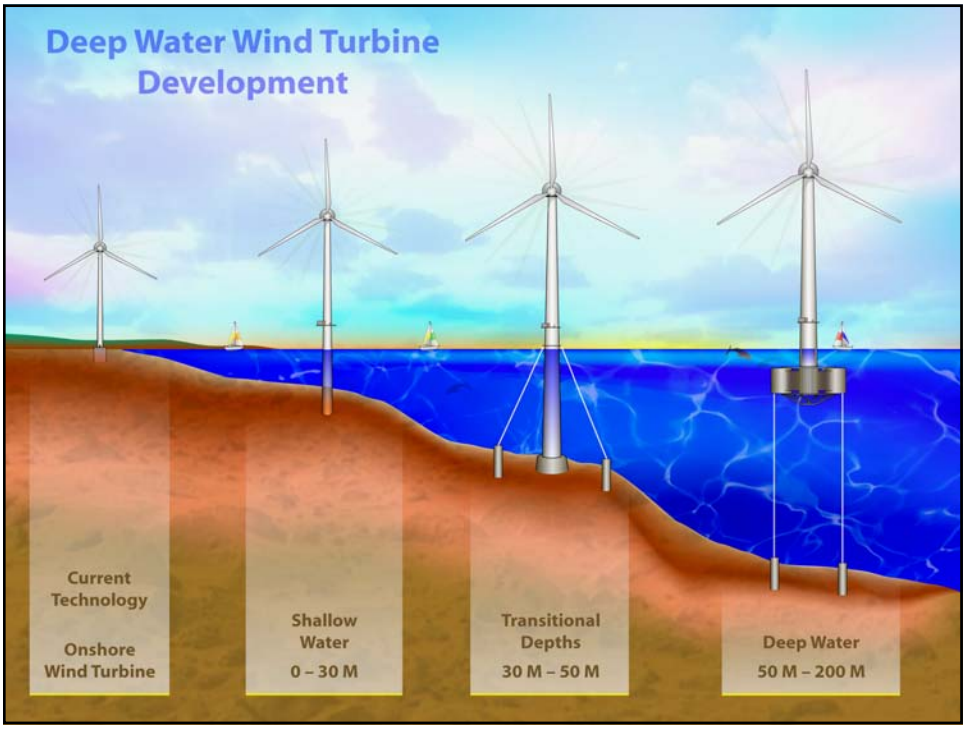
Lifting nacelle

Photos: Courtesy GE Wind and hornsrev.dk

Offshore Installation (2)




Photos: Courtesy GE Wind



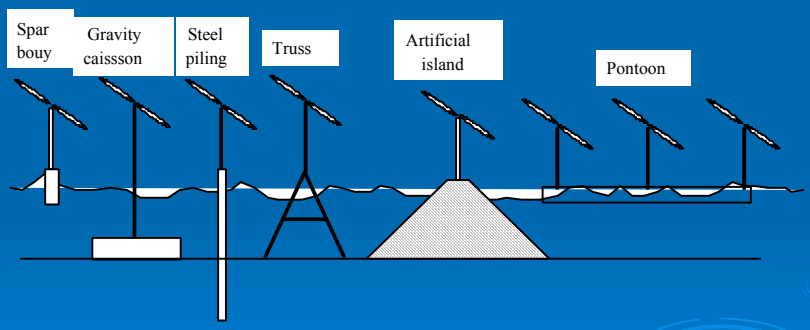
Why Go into Deeper Waters

- US waters are deeper than European coastal waters
- Greater resource potential over broad area
- Higher winds
- Mitigates visual impacts

Technical Considerations

- More extreme external conditions
- Greater cable length
- Pushing the limits of the monopile technology
  - Larger foundation costs
- Platform costs have a high uncertainty
  - R&D for floating supports
- Environmental uncertainties

Support Options for Offshore Wind Turbines

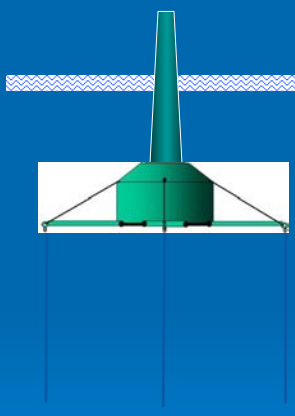


Courtesy of Jim Manwell, University of Massachusetts

Floating Wind Turbine Platforms

Dutch Tri-floater

Studie narr haalbaarheid van en randvoorwaarden voor drijvende offshore windturbines. ECN, MARIN, Lagerwey the Windmaster, TNO, TUD, MSC, Dec. 2002.



- **5-MW Turbine**
- **Steel Buoyancy Tank**
- **Three Radial Arms – 60-m spacing**
- **Vertical moorings**
- **2 tendons per arm**
- **SF=2.0 buoyancy**

NREL Mono-column TPL

Musial, W.D, Butterfield, C.P. and Boone, A.,"Feasibility of Floating Platform Systems For Wind Turbines" Proceedings of AIAA/ASME w\Wind Energy Symposium, AIAA-2004-1007, January, 2004.

NREL Research

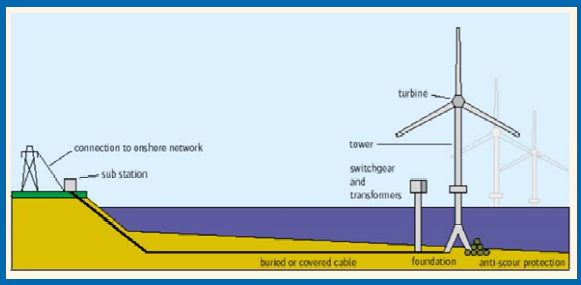
- Low Wind Speed Technologies, Phase II (NREL,SNL)
- Resource mapping
- Environmental policies, permitting & laws
- Gap analysis of existing research
- Technical workshops
- International Energy Agency
- Technology characterization
- Deep water technology R&D
- Standards development
- Outreach

Selected Results to Date

- Environmental regulations & agencies
- US Army Corp of Engineers permit process
- European environmental studies
- Technical Workshops held in 2003
  - Offshore Stakeholder Dialogue Meeting (July)
  - Boston Technical Tutorial Meeting (September)
  - Deep Water Technologies Workshop (October)

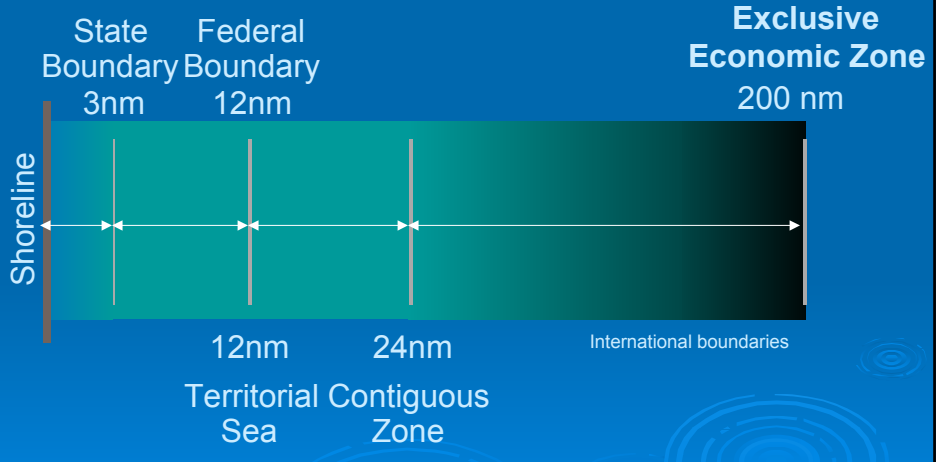
Factors Determining Applicable Regulations

- Project Size, Location and Construction
- State/Federal Ocean Boundaries



- Landfall Grid Connection
- Sensitive Marine/Land Areas
- Avian and Marine Species
- Activities and Uses of Project Area

Ocean Jurisdictions



Note: TX & Gulf coast of FL state boundaries are 9 nm

Not to Scale

Potential Effects/Concerns

- Sea mammals
- Fisheries
- Avian
- Hydrography & Coastal effects
- Seabed/Artificial Reef
- Viewshed
- Socioeconomics
- Community acceptance
- Noise/Vibrations
- Radar/Radio Disturbances (military/commercial uses)
- Logistics Traffic
- Transmission Lines
- Subsea Cables/ Electromagnetic Fields
- Navigation & Risk collision
- Air Traffic Safety
- Marine Archaeology
- Cumulative Effects (e.g., air quality)

Selected Federal Regulations

Legislative Authority	Major Program/Permit	Lead Agencies
Rivers And Harbors Act - Section 10	Prohibits the obstruction or alteration of navigable water of the U.S without a permit	U.S. Army Corps of Engineers (District Office)
National Environmental Policy Act (NEPA)	Requires submission of an environmental review for all major federal actions that may significantly affect the quality of the human environment	U.S. Army Corps of Engineers (District) Council on Environmental Quality
Coastal Zone Management Act	Consistency determination with the coastal program of the affected state	NOAA State Coastal Zone Management Agencies
Navigation and Navigable Waters	Navigation aid permit (markings and lighting)	U.S. Coast Guard
Navigational Hazard to Air Traffic	Determination of the safe use of airspace from construction start (lighting)	U.S Federal Aviation Administration (Regional Administrator)

Selected Federal Regulations

Legislative Authority	Major Program/Permit	Lead Agencies
Migratory Bird Treaty Act	No "taking" or harming of birds determination	Fish and Wildlife Service Migratory Bird Conservation Commission
National Historic Preservation Act	Consultation on the protection of historic resources — places, properties, shipwrecks	Department of the Interior State Historic Preservation Offices
Magnuson-Stevens Fishery Conservation & Management Act	Conserves & manages fish stocks to a 200-mile fishery conservation zone & designates essential fish habitat	National Marine Fisheries Service
National Marine Sanctuary Act (Title III)	Designates marine protected areas	National Ocean Service (NOAA)
Endangered Species Act	Consultation on action that may jeopardize threatened & endangered (listed) species or adversely modify critical habitat	Fish & Wildlife Service National Marine Fisheries Service

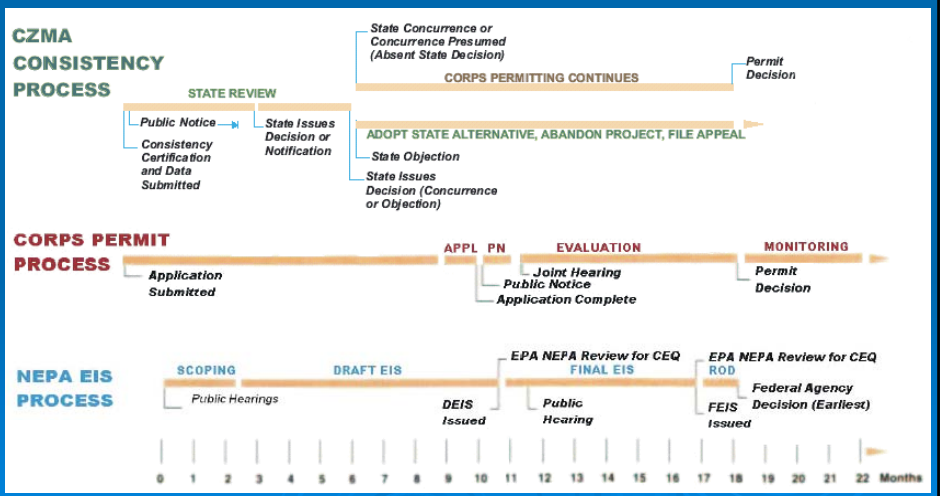
Selected Federal Regulations

Legislative Authority	Major Program/Permit	Lead Agency
Marine Mammal Protection Act	Prohibits or strictly limits the direct of indirect taking or harassment (Permits may be sought for "incidental take")	Fish & Wildlife National Marine Fisheries Service
Submerged Lands Act	Grants a lease for public lands held in trust by the government	Minerals Management Service
Outer Continental Shelf Lands Act	Manages the OCS with leasing rights for minerals production. Also covers artificial islands, ,installations, and other devices located on the seabed	Minerals Management Service
Clean Water Act	Regulates discharges of pollutants into the waters of the United States	U.S. Environmental Protection Agency
Estuary Protection Act	Conserves estuarine areas	Fish and Wildlife Service

Selected State and Local Authorities

- Selected State Permits/Licenses/Approvals
  - Environmental Quality Review Boards
  - Coastal Zone Management Programs
  - Siting Boards for Energy Facilities and Transmission Lines
  - State Parks, Forests, and Cultural & Historic Resources
  - Tidal Wetlands, Coastal Erosion Hazard, Water Quality
- Local Land Use Entities
  - Town Planning Boards
  - Zoning Boards
  - By-laws (e.g., setbacks)

U.S. Army Corp of Engineers Permit and NEPA Process



Reference: Adapted from USACE presentation, Karen Adams

Cape Wind
Nantucket Sound

- 468 MW = 130 3.6 MW GE turbines
- About 24 square miles
- Two lawsuits
  - Ten Taxpayers Citizen Group vs. Cape Wind Associates (8/03)
  - Alliance vs. US Army Corp of Engineers (9/03)
- Meteorological Tower installed
- Draft environmental impact statement (EIS) expected this year
- Lack of political support

http://www.capewind.org/

179 feet installed at Horseshoe Shoal

Cape Wind View Simulations

An impact study commissioned by the developer of what the wind farm in Nantucket Sound would look like about 7 miles from Craigville Beach.

Source: Cape Wind web site, www.capewind.org

Community Involvement

- Primary Objective of the Permit is Public Involvement
  - Public hearings
  - Interagency cooperation
  - Environmental Impact Statement
  - Citizen lawsuits
  - Extensive stakeholder process for Cape Wind
    - http://www.mtpc.org/offshore/index.htm

Long Island Power Authority
Long Island Sound

- 100 -150 MW
- LIPA - a municipal utility
  - Guaranteeing purchase power agreement
  - Substation construction
- Early public involvement process
- Strong state political support

LIPA View Simulations

7.5 miles
from shore

Source: LIPA website www.lipower.org

LIPA View Simulations

3 miles off

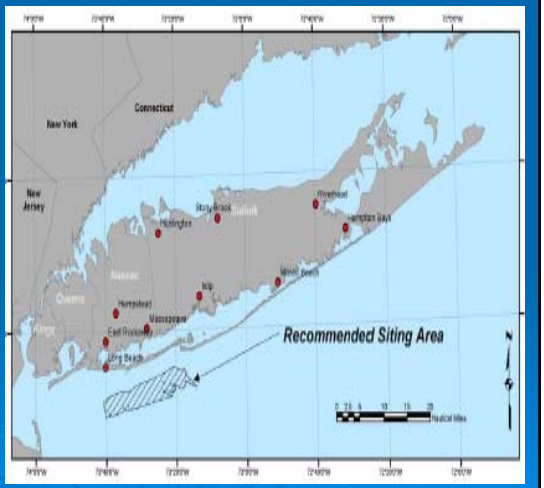
Jones Beach

Source: LIPA website www.lipower.org

Long Island Power Authority Jones Beach

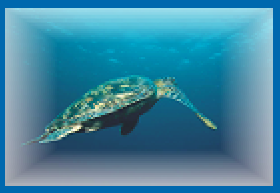
- Phase I and II Studies (Jan. 2003) funded by LIPA and NY State Energy Research & Development Administration (NYSERDA)
- Competitive period from 22 Jan. 2003 - 1 May 2003
- LIPA selected FPL as the developer in May 2004

http://lioffshorewindenergy.org/



Uncertainties

- Dialogues With Regulators
  - Ecological effects & risk levels
  - Best available data & standards
  - Environmental benefits
  - Multiple agencies with different jurisdictions
- No personal experience with the technology
  - Educate early and encourage debate
- Market-driven development requires due diligence
  - Section 10 applications filed but never completed



No Consistent Policy!

- No national energy strategy or plan
  - Agencies setting their own policies
  - States are taking the lead
- Muddled institutional & legal boundaries
  - Jurisdictional control may shift
  - No clear legal authority within the outer continental shelf

Learning Curve

- History of avian/bat issues
  - Altamont site in California tarnished green image
  - Cumulative effects
  - Need standardized protocols
  - Lack of baseline data
  - Need collaboration to define & fund studies

NREL Avian Library Available at:
www.nrel.gov/wind/avian_lit.html

- Viewshed is important
  - Not near my beach!
  - "Put it further away in deeper water!"

Learning from the Europeans

- A national energy policy works
  - Political will and financial incentives
  - Lawsuits not typical
- Climate change motivated the offshore wind policy!
- Establishing "zones for development" is reasonable

Learning From the Europeans

- Subsidized demonstration projects are critical
  - Learning curves
  - Speeds up initial research & approval stages
- No significant environmental effects identified
  - Good baseline studies are critical
  - Scientifically rigorous results
  - Before-After-Control-Impact methodologies
  - Study design and results must be peer reviewed
  - Preliminary conclusions across sites are lacking

Critical Issues

Wind resource is not an issue!

- Public acceptance
- Possible environmental issues
- Grid connections on large projects
- Market perspective --- politics should provide long term policy!
- Financial and technical risks
- Alternative uses of the ocean
- Cost reduction of investment costs

Summary

- Offshore wind energy is a reality in shallow water, close to shore
- Cost of energy higher than from conventional sources -- ignoring externalities
- Technology for moderately deep water still expensive (> 30 m)
- Technology for deeper water, far from shore remains to be developed

Recommendations for the Great Lakes

- Resource assessment
- Conduct feasibility studies
  - Designate zones
- Strategic planning
- One-stop shop for permitting
  - Investigate requirements/jurisdictions
  - Due diligence
- State financial resources for baseline studies & outreach
- Engineering studies for Lake Michigan

A Future Vision for Wind Energy

2002

Bulk Power Generator
4-6¢ at 15mph

- Land Based
- Bulk Electricity
- Wind Farms

Potential 20% of Electricity Market

Land Based Technology Path

Land Based LWST Large – Scale 2 - 5 MW

Transmission Barriers

Offshore Technology Path

Offshore Turbines 5 MW & Larger

Cost & Regulatory Barriers

Wind-Hydrogen Path

Land & Ocean Large & Small "Hydrogen Turbines"

Cost & Infrastructure Barriers

Future

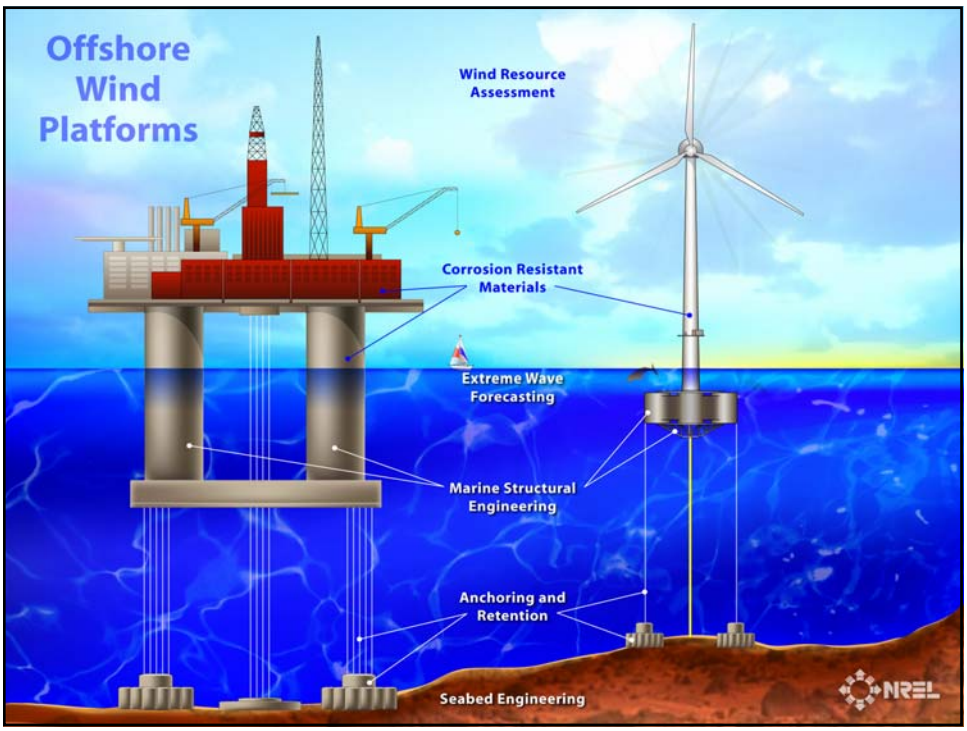
Low Wind Speed Technology
3¢/kWh at 13mph
20% of Electricity
2010

Unique Offshore Designs
- Shallow water
- ***Deep water***

Higher Wind Sites
2010 & Beyond

Dual Output Turbines
- Transportation
- Firm Electricity
- Industrial
- Residential

Multi-sector Market
2030 & Beyond



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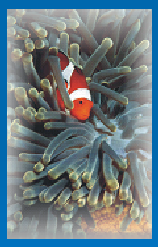

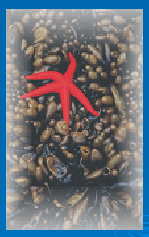


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  http://uk.nystedhavmoellepark.dk/frames.asp?Page_ID=44&Page_Ref=44&Templates_ID=1
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- Overview of the UK Offshore Wind Program
  http://www.thecrownestate.co.uk/34_wind_farms_04_02_07.htm
- Germanischer Lloyd WindEnergie GmbH (GL Wind) Research Platform in the North Sea http://www.fino-offshore.com/
- Seven ecological assessment projects http://www.minos-info.org/
- German government offshore wind strategy
  (see http://www.offshore-wind.de/media/article000352/offshore%20strategy%20of%20federal%20government.pdf)

References

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- Council of Europe – Summary of bird studies http://www.coe.int/t/e/Cultural_Co-operation/Environment/Nature_and_biological_diversity/Nature_protection/sc23_inf12e.pdf?L=E
- National Wind Coordinating Committee meeting on "Offshore Wind Developments in the U.S. http://www.nationalwind.org/events/offshore/030701/default.htm
- DOE/ NREL Technical Tutorial on Wind Energy Systems http://www.nrel.gov/wind_meetings/boston_meeting/
- DOE/NREL Workshop on Deep Water Offshore Wind Energy Systems http://www.nrel.gov/wind_meetings/offshore_wind/